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A METHOD OF ESTIMATING FACE FLY POPULATIONS ON CATTLE

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During the past 10 years or so the face fly (Musca autumnalis De Geer), previously unknown in North America, suddenly erupted into prominence in the United States as a pest of cattle over most of the northeast quadrant of the Nation. Sabrosky (1961) has reviewed the relevant information regarding the discovery and spread of this fly. The rate of spread through 1960, as indicated by the records cited by Sabrosky, appears to be in the order of a geometric progression, with the most spread occurring during the last 2 years of that 10-year period.

Unfortunately, the biological significance of these records is somewhat clouded by evidence that entomologists did not begin to seriously look for the fly until after March 1959, when notice of its discovery in Virginia was published in the Cooperative Economic Insect Report (Plant Pest Control Division, Agr. Res. Serv., U.S. Dept. Agr., 1959).

Once the presence of autumnalis in the United States was publicized, it immediately aroused a great deal of interest. This is scarcely surprising, in view of its status as a second species of Musca in the Western Hemisphere and its known importance as a livestock pest in Europe. In hindsight, we can regret that this interest was not immediately coordinated, and standardized data-collecting methods adopted. Several attempts were made to record populations of the fly in particular areas, but these attempts failed to provide data of comparative value because no standardized method of obtaining the counts was available to survey entomologists. An examination of items from the Cooperative Economic Insect Report, published in 1959-60 and 61, shows that methods of reporting face fly populations vary considerably from State to State. Reports from some States were regularly in such terms as "abundant" or "few." In reports from other States, estimates were commonly qualified by such indefinite designations as "about," "generally," or "usually." Thus the reader of these reports cannot be confident of the estimate. An even more troublesome kind of report provided an estimate on a "per-head" basis. The reader cannot be sure whether the estimate was based on the number of flies on the animal's head or the number on the entire animal.

Research entomologists engaged in insecticide or repellancy tests have used several methods for obtaining counts. Flies on the animal's face were counted by Holdsworth (1962). Dobson and Hubner (1961), Granett and Hansens (1961), Fales, et al. (1961), and Anonymous (1961) counted all flies on the animal's head, whereas Cheng, et al.(1962), Matthysse (1961), Bruce, et al.(1960), Decker (1961) counted flies on the entire body. It is doubtful that these methods were more accurate than the method we have used, which is restricted to counting the number of flies around the eyes of the animal. When one is counting a fly population, a good part of which is in flight around an animal, the problem of large sample size becomes especially acute.

The present research was conducted to find a method of estimating face fly populations that would be easy to use, and provide some degree of confidence in the results. Such a method is a necessary prerequisite to comparisons of populations in Europe and in the United States. These comparisons will be valuable in determining whether a significant difference exists in the environments affecting the fly on the two continents. Lower populations in the European habitats of the insect species would suggest the existence on that continent of important natural enemies. In addition to finding an efficient method of obtaining face fly population counts, information on diurnal and seasonal activity and abundance of the fly in France appeared desirable. Our tests were set up to facilitate the accumulation of both sets of desired data.

In our studies, the most satisfactory subsample count was determined to be that of flies congregated around the eyes of the animal, and was selected for the following reasons: (1) When population levels are low, the location around the eye is the favored spot for feeding; (2) the eye area, unlike the nostrils, is always available to the flies (when the animals are feeding, few flies can rest on the nostrils); (3) the flies on the rest of the face and on the horns are moving around more and are thus harder to count accurately; and (4) other species of flies are usually found on other parts of the animal but seldom around the eyes. Thus, as soon as the relationship between the "eye counts" and the total population is understood, a method for comparing populations is available, and the observer may utilize either the eye-count average used as an index of value or the total population with its confidence intervals, as given in table 2.

The following is, for the most part, a statistical study based on data obtained at the Haras de Jardy, a stud farm maintained by M. Boussac, a Paris industrialist, in the commune of Vaucresson of the Department of the Seine et Oise.

Methods and Materials

A herd of 23 Charolais steers 3-1/2 years old was maintained in three fields of the Haras. The fields lie in a straight line north to south. Field 1, the most northern, is separated from the other two fields by the "Autoroute de l'Ouest," consisting of a park-like strip of land about 200 yards wide and a narrow road. The southern boundary of field 2 and northern boundary of field 3 are contiguous, except for a drive-in strip about 20 yards wide. Field 1 was utilized as pasture for the first time in 1961; the other two have been used as pastures for many years.

The steers were divided into two groups—14 placed in field 1, and 9 in field 2. About the first of June the animals in field 1 were removed to field 3, where they remained until about June 30, when they were again divided; 10 were returned to field 1, and 4 were allowed to remain in field 3. About July 5 the 4 animals were pastured in field 2; thus, on this date, 13 animals were pastured in field 2, and 10 in field 1. During early October the number of steers was reduced to 12, all of which were placed in field 2.

Data were taken from May 1 to September 8, 1961, with the aid of 7-power binoculars plus the naked eye as the observer stood within a short distance from the animals. Data were fed into a small, battery-operated tape recorder and consisted of fly counts from the right and left eye, the face (including horns), and the entire body. Temperatures prevailing at the time counts were made ranged from 14° to 23° C. Within this range

there was no correlation between temperature and fly activity. Below 14° C. (57.2 F.) activity was observed to drop abruptly. The upper limit of optimum temperature was not established as no observations were made at a temperature higher than 23°C. (73°F.).

A different distribution pattern seemed to occur on animals lying down chewing their cud. An attempt was made to get counts from these animals, but the number of samples proved too small to permit proper evaluation.

Analysis of Data

From all counts made, the 27 subsamples included in table 1 were selected to represent those from a normal herd (at least four animals in the same field). Counts from the left eye were compared with those from the right eye to (1) avoid having to count the flies on both eyes of each animal, since in a rapid survey of a herd both eyes can rarely be seen at the same time, and (2) eliminate any subjective bias that might have been introduced in the counting. Results showed that means from the right and left eye could be used equally well in deriving population means, and eight single eye counts were chosen as the minimum number for valid statistical results.

Based on the above reasoning, eye counts from the areas around each eye were combined so that the eye-count average in each subsample was more precise statistically than the total per-animal average. At this point in the analysis it was assumed that eye counts were known to be without error, and a third-degree curvilinear regression was computed, with the eye-count average as the independent variable. The assumption that eye counts were without error, employed to simplify the analysis, required that a minimum number of eye counts be set. It also indicated that when more than the minimum number of eye counts were used to obtain an individual eye-count average, the assumption underlying the regression would still be justified.

The matrix of the sums of squares and cross products, where $x_1 = x$, $x_2 = x^2$, and $x_3 = x^3$, was:

$$\left[x \right] = \begin{bmatrix} 133.0100 & 1,185.8760 & 9,866.0576 \\ 1,185.8760 & 11,579.9646 & 102,250.8068 \\ 9,866.0576 & 102,250.8068 & 940,966.0452 \end{bmatrix}$$

This above matrix was inverted, and one iteration of the Hotelling method for improving the accuracy of the inverse was used, giving:

$$\left[x \right]^{-1} = \begin{bmatrix} 0.512\,159\,394 & -0.124\,295\,707 & 0.008\,136\,685 \\ -0.124\,295\,767 & 0.032.296\,375 & -0.002\,206\,484 \\ 0.008\,136\,689 & -0.002\,206\,484 & 0.000\,155\,518 \end{bmatrix}$$

which, on being multiplied by $\left[x_i\, y \right] = \begin{bmatrix} 942.61 \\ 9,287.638 \\ 83,080.762 \end{bmatrix}$ on the left, gives the

following equation:

$$\hat{Y} = 4.356\,268\,x - 0.503.513\,x^2 + 0.097\,276\,x^3$$

The sum of squares from the regression line is:

$$SSR = b_1 \Sigma x_1 y + b_2 \Sigma x_2 y + b_3 \Sigma x_3 y$$

$$= (4.356\,268)(942.61) - (0.503\,513)(9,287.628) + (0.097\,276)(83,080.762)$$

$$= 7511.5845$$

and $$SSE = \Sigma y^2 - SSR = 7630.61 - 7511.58 = 119.03$$

$$S^2 = \frac{SSE}{n-(r+1)} = \frac{119.03}{27-4} = \frac{119.03}{23} = 5.175$$

In order to compute table 2, the last ten values of the table were computed to 9 decimal places, all terminal values were determined by the method of differences, and the entire table built up in increments of one tenth (0.1).

The terminal values for x = 12 were:

$$Y = 147.862\,272\,000$$
$$\Delta 1 = -3.399\,631\,846$$
$$\Delta 2 = 0.059\,384\,804$$
$$\Delta 3 = 0.000\,583\,656$$

Table 2 also includes the 1 percent confidence interval for an individual estimate, Y*, at any value of x. These values were obtained by solving the following relationship:

$$\sigma^2_{Y^*} = S^2 + S^2 \left\{ \frac{1}{n} + \sum C_{ij} \cdot x'_i \cdot x'_j \right\}$$

where $x' = (x_i - \bar{x}_i)$ and C_{ij} is the inverse matrix given above.

The values in the table are obtained as follows:

$$1 \text{ percent limit point} = t(.01; 23)\,\sigma_{Y^*} = I$$

and the interval is,

$$(\hat{Y} - I) < Y^* < (\hat{Y} + I)$$

Because of the simplifying assumption, the probability is not exactly 0.01; however, there is enough accuracy for the type of survey that is intended.

Results and Use of Table 2

When data from table 1 were subjected to the above analysis, a direct relationship was seen to exist between the number of face flies around the eyes and the total number on the entire animal. This relationship, however, did not hold for temperatures lower than 14° C. (57.2 F.) The upper temperature limit is not known.

The use of table 2 needs no lengthy explanation. Once the average number of flies per eye is known, the observer will be able to compute the number of flies per animal within a confidence interval lying between 12 percent and 1 percent. The standard error for the expected number was calculated for an individual estimate, and the larger the sample of eye counts used in computing each estimate, the closer one can depend on the 1 percent. In no case should less than eight eye counts be used.

As will be noted in table 2, observations of values between 0 and 3.2 on the eye-count axis show that the relationship between average number of flies per eye and total flies per animal is essentially linear, probably because little competition for a place to feed occurs among the flies. From the value 3.3 on, in table 2, the curve rises sharply and accurate counting of flies around the eyes becomes progressively more difficult. As competition for a place around an eye becomes greater, increasing discomfort to the animal occurs; and, when irritation becomes acute, the animal flaps its ears to dislodge the flies. The procedure followed by the authors was to count the flies before an ear flapping and count them again as they came back to the eye. When total population levels were in the vicinity of 30-40 flies per animal, the eyes began watering quite freely and some of the flies fed on these secretions. This habit was responsible for some of the higher fly counts, since all flies in the eye, around the eye, and on the eye exudates were counted.

It is appreciated that the eye-count method of estimating face fly populations will at best only provide an index value applicable to the population of a particular area. Most males will be feeding on umbelliferous flowers, and many females will be preoccupied by oviposition. However, it seems likely that the eye-count values will represent a reasonably constant proportion of the population , and therefore will be a reliable means of detecting difference in abundance. Since about 20 eye counts can be taken in 10 minutes, the method is relatively fast and should not be tedious.

Summary

Of the possible subsample counts of face flies that may be recorded, those taken from around the eyes were selected as the most statistically sound for computing the total fly count on a given animal for the following reasons: (1) When population levels are low, the area around the eyes is the favored feeding location; (2) the eye area is always available to the flies; and (3) other Diptera species are seldom found around the eyes.

The analysis presented indicates that a direct relationship exists between the average number of flies around the eyes (eye count) and the total population per animal. The relationship does not hold, however, for temperatures lower than 57.2° F. The upper temperature is not known.

When the relationship between eye count and the total population is understood, a method for comparing populations is available, and the observer may utilize either the eye-count average as an index, or the total population with its confidence increments. A table is presented with the values of Y, the estimated total fly population per animal and its confidence increments. The confidence increments lie between 12 percent and 1 percent, and use of these data should provide total per-animal population estimates approaching a 1-percent confidence interval.

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Table 1.--Number of face flies counted on steers in pasture from May 1 to September 8, and temperature at time of each count. (Data used in analysis of eye counts as a means of computing total per-animal populations)

Subsample number	Number of animals in test	Number of flies				Average number of flies per	
		In eye area		On other parts of face	On entire animal 1/	Eye area	Animal
		Right	Left				
1	14 2/	18	21	51	90	1.4	6.4
2	14	30	39	75	144	2.6	10.3
3	12	56	76	178	356	5.5	29.7
4	14	60	73	57	259	4.8	18.5
5	4	25	17	29	86	5.3	21.5
6	14	20	21	15	98	1.5	7.0
7	14	41	30	66	157	2.5	11.2
8	14	5	7	5	41	0.4	2.9
9	14	16	10	19	69	0.9	4.9
10	14	20	15	16	53	1.3	3.8
11	10	36	24	41	104	3.0	10.4
12	9	23	20	52	102	2.4	11.3
13	4	12	20	21	77	4.0	19.3
14	11	21	34	23	89	2.5	8.1
15	4	3	5	2	20	1.0	5.0
16	10	76	80	177	472	7.8	47.2
17	13	51	45	76	212	3.7	16.3
18	13	73	92	226	414	6.3	31.8
19	10	100	92	388	825	9.6	82.5
20	10	6	1	0	7	0.4	0.7
21	10	12	16	1	29	1.4	2.9
22	10	24	16	3	54	2.0	5.4
23	10	34	23	9	77	2.9	7.7
24	10	33	27	8	78	3.0	7.8
25	10	13	10	1	42	1.2	4.2
26	10	31	17	13	84	2.4	8.4
27	10	12	23	41	96	1.8	9.6

1/ Total includes sum of flies on eyes and face plus those on other parts of the body.

2/ Flies on only the left eye were counted on one animal, so that only 27 eyes were used for the average number of flies per eye.

Table 2.—Values of Y and the confidence increment for estimating total face fly population per animal by count of flies around the eyes of the animal.

Average number of flies per eye (X axis)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.0+ 8.0 [1/]	0.4+ 7.8	0.9+ 7.5	1.3+ 7.4	1.7+ 7.2	2.1+ 7.1	2.5+ 7.0	2.8+ 6.9	3.2+ 6.8	3.6+ 6.7
1	4.0+ 6.7	4.3+ 6.7	4.7+ 6.6	5.0+ 6.6	5.4+ 6.6	5.7+ 6.6	6.1+ 6.6	6.4+ 6.6	6.8+ 6.6	7.1+ 6.6
2	7.5± 6.6	7.8± 6.6	8.2± 6.6	8.5± 6.6	8.9± 6.6	9.3± 6.6	9.6± 6.6	10.0± 6.6	10.4± 6.6	10.8± 6.6
3	11.2± 6.6	11.6± 6.6	12.0± 6.6	12.4± 6.6	12.8± 6.6	13.3± 6.6	13.7± 6.7	14.2± 6.7	14.6± 6.7	15.1± 6.7
4	15.6± 6.7	16.1± 6.7	16.6± 6.7	17.2± 6.7	17.7± 6.7	18.3± 6.7	18.9± 6.7	19.5± 6.8	20.1± 6.8	20.7± 6.8
5	21.4± 6.8	22.0± 6.8	22.7 ± 6.9	23.4± 6.9	24.2± 6.9	24.9± 6.9	25.7± 7.0	26.5± 7.0	27.3± 7.0	28.2± 7.1
6	29.0± 7.1	29.9± 7.1	30.8± 7.1	31.8± 7.2	32.8± 7.2	33.8± 7.2	34.8± 7.2	35.8± 7.2	36.9± 7.3	38.0± 7.3
7	39.2± 7.3	40.4± 7.3	41.6± 7.3	42.8± 7.3	44.1± 7.3	45.4± 7.3	46.7± 7.3	48.1± 7.3	49.5± 7.4	51.0± 7.4
8	52.4± 7.4	53.9± 7.4	55.5± 7.4	57.1± 7.4	58.7± 7.4	60.4± 7.5	62.1± 7.5	63.8± 7.6	65.6± 7.6	67.5± 7.7
9	69.3± 7.8	71.3± 7.9	73.2± 8.0	75.3± 8.2	77.3± 8.4	79.3± 8.4	81.5± 8.8	83.7± 9.1 [2/]	85.9± 9.4	88.2± 7.7
10	90.5±10.1	92.8±10.4	95.3±10.9	97.7±11.3	100.2±11.8	102.8±12.4	105.5±13.0	108.1±13.5	110.9±14.2	113.6±13.5
11	116.5±15.6	119.4±16.3	122.3±17.1	125.3±17.9	128.3±18.8	131.5±19.7	134.6±20.7	137.8±21.6	141.1±22.7	144.5±22.7
12	147.9±25.5									

1/ All values with only a plus sign before the confidence increment indicate that the lower limit is the X axis or zero.

2/ All values above an eye-count average of 9.6 have been extrapolated and should be used with caution.